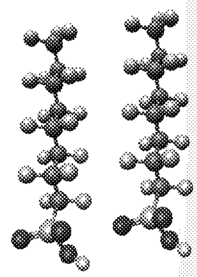
Briefing to David Dunlap
November 19, 2018
Via Video: Cincinnati, OH

# PFAS Treatment and Remediation

**Purpose:** To discuss EPA's research program on PFAS treatment technologies including state of the science, current and future projects, collaborations, and outreach for both drinking water and remediation of contaminated sites





*Perfluorooctanesulfonic acid (PFOS)*

# Drinking Water Treatment Overview

- **Problem**: Utilities lack performance and cost data on PFAS removal
- **Action**:
  - Conduct in-house drinking water treatment performance projects
  - Gather performance and cost data from available sources (EPA, DOD, utilities, suppliers, industry, etc.)
  - Update **EPA's Drinking Water Treatability Database**
  - Compare costs and cost models across different entities
  - Update **EPA's Unit Cost Models** to address PFAS
  - Connect Treatability Database to the Unit Cost Models for ease of operation
  - Model performance and cost, and then extrapolate to other scenarios (variable influent concentrations, number of PFAS, regeneration frequency, etc.)
- **Results**: Tools, data, and support for the utility's selection of optimal treatment choice
- **Impact**: Enable utilities to make informed decisions about cost-effective treatment strategies for removing PFAS from drinking water while avoiding unintended consequences and maximizing secondary benefits (improved compliance with other rulemaking)

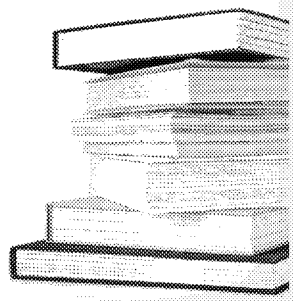
# Drinking Water Treatability Database

## Publically Available Database

- Interactive literature review database that contains over 65 regulated and unregulated contaminants and covers 34 treatment processes commonly employed or known to be effective (thousands of sources assembled on one site)
- PFOA & PFOS: Pages currently available
- PFNA, PFHxA, PFHxS, PFBS, Gen-X: Pages were added (June, 2018) for activated carbon, ion exchange, and membrane separation
- **Other PFAS and technologies to follow**

Search: EPA TDB
http://iaspub.epa.gov/tdb/pages/general/home.do

https://www.epa.gov/pfas/epa-pfas-data-and-tools





Background on TDB and link.
Stress that PFAS are now in the TDB.

You can find it by Googling EPA TDB

# Drinking Water Treatment for PFOS

**Ineffective Treatments**

Conventional Treatment
Low Pressure Membranes
Biological Treatment (including slow sand filtration)
Disinfection
Oxidation
Advanced oxidation

| PAC Dose to Achieve | |
|---|---|
| 50% Removal | 16 mg/l |
| 90% Removal | >50 mg/L |

*Dudley et al., 2015*

| Effective Treatments | Percent Removal | |
|---|---|---|
| Anion Exchange Resin (IEX) | 90 to 99 | - Effective |
| High Pressure Membranes | 93 to 99 | - Effective |
| Powdered Activated Carbon (PAC) | 10 to 97 | - **Effective for only select applications** |
| Granular Activated Carbon (GAC) | | |
| Extended Run Time | 0 to 26 | - **Ineffective** |
| Designed for PFAS Removal | > 89 to > 98 | - Effective |

4

You see the exact same trend for PFOS. Go over data quickly.

Ion exchange is slightly more effective, as expected.

Because of its data set, its effectiveness, and the general use of GAC to treat PFOA/PFOS; let's concentrate on GAC. When designing a GAC system, one would concentrate on PFOA because it will break through the bed before PFOS.

## GAC Treatment Cost Modeling

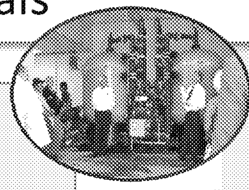
**Deliberative Process / Ex. 5**

5

To demonstrate this, the costs are compared to TCE (which has a similar Freundlich K value to PFOA). TCE is known to be cost effectively removed by GAC. 11DCA is also shown. 11DCA, like cis1,2 DCE, is known to be a contaminant that is on the boundary of cost effectiveness. From the plot you can see that the cost of PFOA treatment is less than 11 DCA. At low flows, costs becomes less sensitive to treatment capacity.

TCE: 2,000 ug/g (L/ug)1/n
PFOA: 1,600 ug/g (L/ug)1/n
11DCA: 65 ug/g (L/ug)1/n
PFOS: 2,300 ug/g (L/ug)1/n

# Utility Drinking Water Goals



**For utilities that have PFAS in their source water at concentrations of health concern**

1) Eliminate source of PFAS to the source water
2) Either choose a new source of water or choose a **technology, design, and operational scheme** that will reduce PFAS to safe levels at the lowest possible cost in a **robust, reliable, and sustainable manner** that avoids unintended consequences

**Issues to address (not inclusive)**

1) Capital and operating costs are affordable
2) Staff can handle operational scheme over the long term
3) Technology can operate long term under a reasonable maintenance program
4) Technology and treatment train can handle source water quality changes
5) Any waste stream generated can be treated or disposed in a sustainable and cost-effective manner over the long term
6) Meets all other regulations



.

Overall Goals for DW treatment

# Current Drinking Water Projects

**Cape Fear Public Utility Authority (Wilmington, NC)**
- Modeling performance and extrapolating to other scenarios (variable influent concentrations, number of PFAS, regeneration frequency, number of columns, etc.)

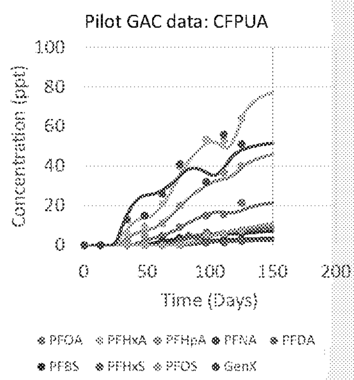
**Air Force Institute of Technology / Air Force Civil Engineer Center**
- Air Force will share their treatment data and AFIT will run EPA cost models for use as means to compare technologies on a cost basis – extensions to SERDP and ESTCP programs

**Calgon Carbon and Evoqua (manufacturers of treatment systems)**
- Sharing data from their pilot and full-scale systems
- Collaboration on an activated carbon reactivation study

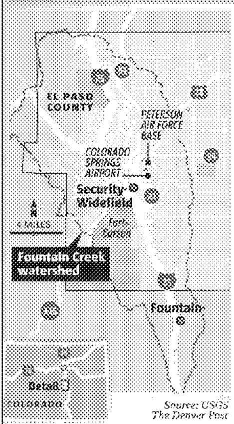
**Greensboro, NC**
- Sharing treatment data and coordinating on a source identification effort

**Fayetteville, NC**
- Sharing treatment data

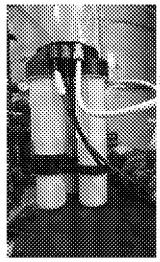
**Regions, Water Research Foundation, and other communities**

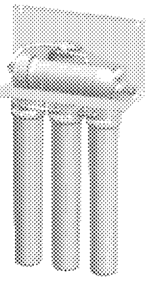


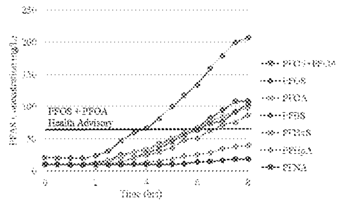
# Research: Drinking Water Treatment Costs




- **Problem**: Lack of data for home treatment devices
- **Action**: Conduct a study of activated carbon and reverse osmosis point-of-use (POU) and point of entry (POE) devices based on the water from the quality in the Widefield Aquifer in Colorado
- **Results**: Under these conditions, if properly designed, POU/POE water systems can provide relatively inexpensive treatment barriers for PFAS removal in the home
- **Impact**:
  - Enable homeowners and utilities to make more informed choices.
  - Provide additional treatment and cost data for databases







# Annual Small Drinking Water Workshop

**2018 Workshop (August):**

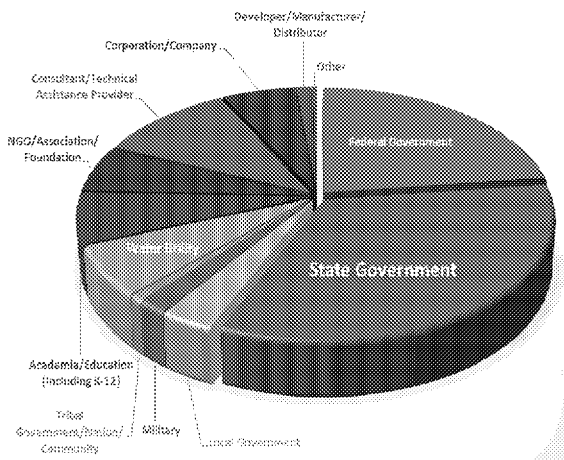
- **Total attendees: 376**
  - States (and DC): **46**
  - U.S. Territories: **3**
  - Tribal Nations: **2**

**Webinars from Workshop:**

- **Three Live Broadcasts: 2,793**
  - PFAS Session: **1,267**

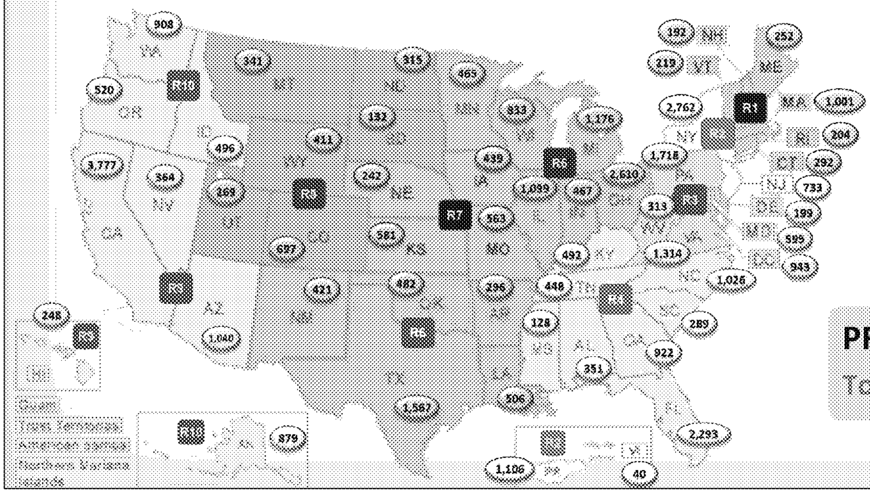
    State & Tribes: **552**

    Local Gov & Military: **270**



# EPA's Monthly Small System Webinar Series

**Attendees:** **January 2015 – October 2018**




## Cumulative Numbers

- 40,426 Attendees
- 25,416 Education Credits
- All 50 States
- 58 Tribal Nations
- 4 U.S. Territories

## Affiliation Percentages

- [illegible] State Government
- 21% Local Government / Utility
- 12% Federal Government

**PFAS Webinar** **(October, 2018)**

Total attendees: 1,391*

EPA

# Remediation Overview

## Source/Site Characterization and Remediation

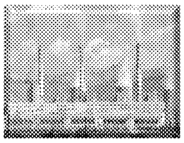
1. **Site Characterization and Source Identification** - Collecting data on PFAS environmental concentrations and sources to support state, regional, and federal partners.

2. **Treatment and Remediation Technologies for PFAS Contaminated Media** - Develop and evaluate risk management options (treatment or remediation) for PFAS-contaminated environmental media.

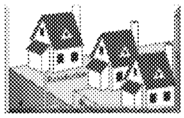
3. **Technical Support for PFAS Contaminated Sites** - Supporting state, regional, tribal, community, and federal partners to (1) evaluate analytical methods, (2) characterize sites/sources, and (3) assess treatment/remediation options for PFAS contaminated environmental media. This support leads to well-informed risk management decisions by EPA and its partners.

## Need to manage the sources

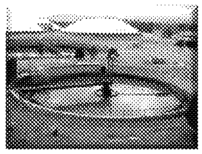
### Sources to water



Primary and Secondary Manufacturing

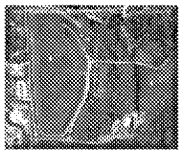


Consumer products use/disposal

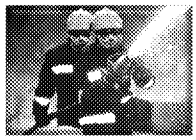


Wastewater plant effluent and biosolids

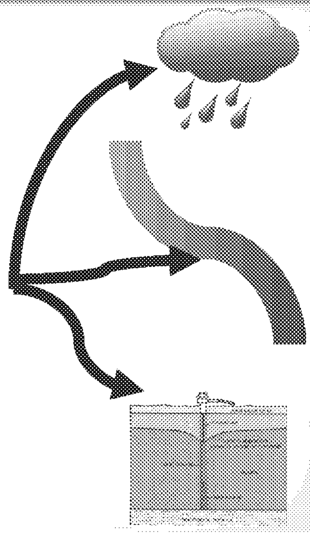
Industrial processes



Landfills and recycling



Direct use in the environment



# Site Characterization Research

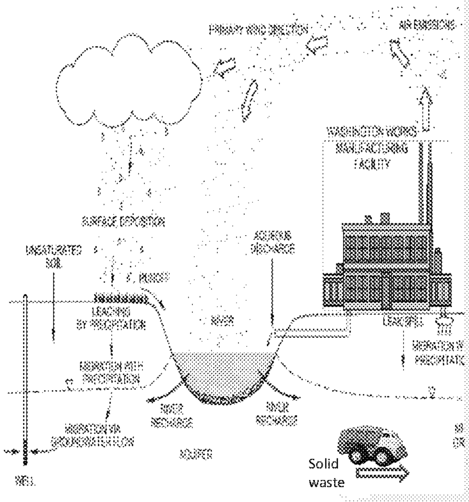
**Research needed to fully understand the appropriate conceptual site model to drive site investigations**

- Needed: mechanistic understanding of the physical, chemical, and biological processes acting on PFAS
- With well defined mechanisms, modeling of fate and transport will allow for characterizing site impacts which will lead to the evaluation and implementation of management and remedies

**Common specific needs from regions, states, tribes, communities, and responsible parties:**

Standard sampling methods and approaches needed to assure integrity of the samples and data, such as…

1. What PFAS do we measure…
   2, 12, 22 analytes …more? Precursors?
2. Need EPA SOPs for PFAS in water, solids, and tissues to assure quality data is used for decision making
3. Total PFAS methods… TOP, TOF…. ?
4. Forensic approaches for source attribution… whose PFAS is this?
5. What are the impacts of co-contaminants?
6. Need models to predict fate and transport






Observations from preliminary site investigations:

Limited sampling to characterize sites

Sampling approach and equipment not evaluated for PFAS

Site characterization and source identification affected by:

Many PFAS-products have varying formulations, chemistries, etc

Lengthy time in environment can result in transformations

Co-contaminants present but not sampled simultaneously

Remediation technologies used for other contaminantsmay impact PFAS concentrations and distributions

## EPA's Remediation Research Activities…

# Wastewater Treatment

**Lab scale**

- PFAS treatment in model wastewater treatment reactors #

**Bench scale**

- Pretreatment technologies for concentrated wastewater streams
- Treatment of emergency response wastes streams

**Full scale**

- Evaluate nine wastewater treatment facilities for treatment of PFAS (+ CECs) *
- Fate of PFAS (+ CECS) during land application of biosolids
- Occurrence and fate of PFAS (+ CECs) within wastewater treatment in DPR facilities*
- Evaluate the impact of wastewater discharge on downstream drinking water treatment including PFAS (+ CECs)

# OPPTS funded * RARE project

# EPA 's Remediation Research Activities…

## Occurrence and impacts of PFAS in complex mixtures

**Emerging Contaminants in Surface Waters**

- Evaluating 40 impacted surface water bodies to evaluate complex mixtures of CECs, including PFAS
- Collaboration with USGS

**Emerging Contaminants in the Great Lakes and their impacts on wildlife**

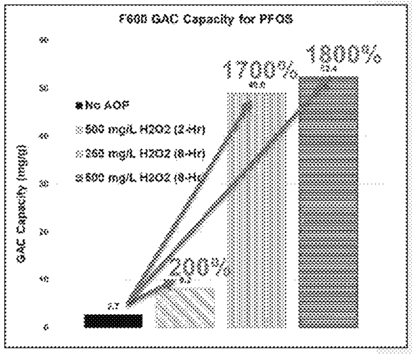
- Includes bioassays and adverse outcome pathway related studies
- Evaluating passive sampling approaches
- Evaluating forensic approach for source allocation or identification
- Collaboration with GLNPO (GLRI), USFW, USGS, USACE, NOAA, and academia

**PFAS occurrence in the Ohio River**

- Collaboration with ORSANCO and States to characterize PFAS in the Ohio River
- Anticipated to start in Spring 2019 to capture low- and high-flow events
- Collaboration with ORSANCO

# Research: Treatment trains for PFAS Treatment with co-contaminants

- **Problem**: Co-contaminants (e.g. petroleum and chlorinated solvents at parts-per-million) can overwhelm technologies targeting PFAS
- **Action**:
  - Develop treatment trains for specific water types (surface, ground, waste, leachate, fire fighting wastes, etc.)
  - Evaluate performance of PFAS treatment technologies along with co-contaminant
- **Results**: Provide performance and cost data for technologies for site and facility managers
- **Impact**: Enable cost effective, site-specific, and mobile management of PFAS during water treatment
- **Collaborators**: DOD, Industry, States/Municipalities, academia

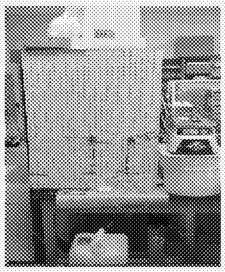



Example improvement in carbon treatment capacity via AOP treatment train in firefighting water containing legacy AFFF

## Bench- to Full-Scale Treatment of PFAS Contaminated Water

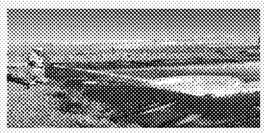
### Collaboration between EPA and DoD

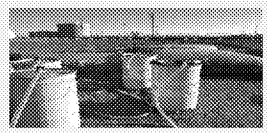
- You just don't treat PFAS – you treat the entire matrix – there are many different waters and challenges
- Need "Toolbox" of technologies to implement "Treatment Trains" for specific sites
- DOD real world applications: Air Force Institute of Technology, Idaho National Laboratory, Joint Base Elmendorf Richardson (Alaska), Rhode Island sites, and SERDP



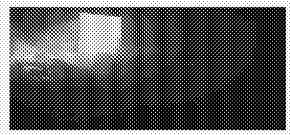
**BENCH** Scale Studies at Air Force Institute of Technology to work out conditions

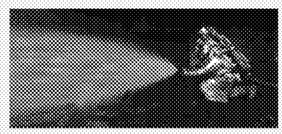
Water Security Test Bed Video: https://youtu.be/olCs_kbegBA





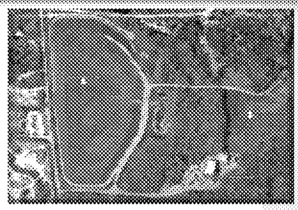
**FULL** Scale Studies at EPA's Water Security Test Bed at Idaho National Laboratory





**APPLIED** at DOD facilities with hangar/building fire suppression systems

# Research: Materials Management



- **Problem**: Lack of knowledge regarding end-of-life management (e.g. landfills, incineration) of PFAS-containing consumer and industrial products
- **Action:**
  - Characterize various end-of-life disposal streams (e.g. municipal, industrial, manufacturing, landfills, incinerators, recycled waste streams) contributing PFAS to the environment
  - Evaluate efficacy of current and advanced waste management technologies (e.g. landfilling, thermal treatment, composting, stabilization) to manage PFAS at end-of-life disposal
  - Evaluate performance and cost data with collaborators to manage these materials and manage PFAS releases to the environment
- **Results**: Provide technologies, data and tools to manage these end of use streams
- **Impact**: Responsible officials will be able to manage effectively end-of-life disposal of PFAS-containing products

# Immobilization Technologies for PFAS-Contaminated Soils

**Existing technologies have limitations**

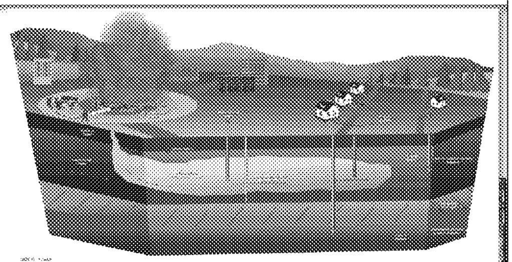
- Excavation and incineration
- Capping

**In-situ strategies are preferred under Superfund**

- Treatment
- Stabilization/Immobilization

**There has been limited research on PFAS stabilization**

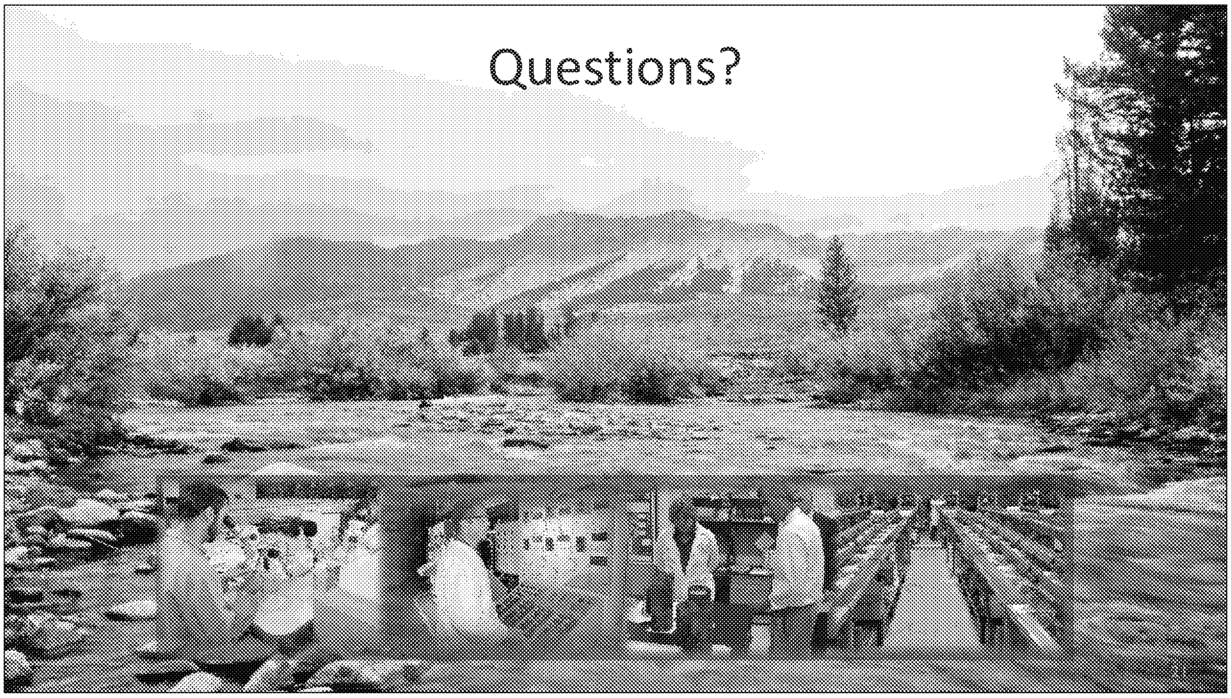
- Stabilization well studied for legacy contaminants
- No comparable data available for PFAS



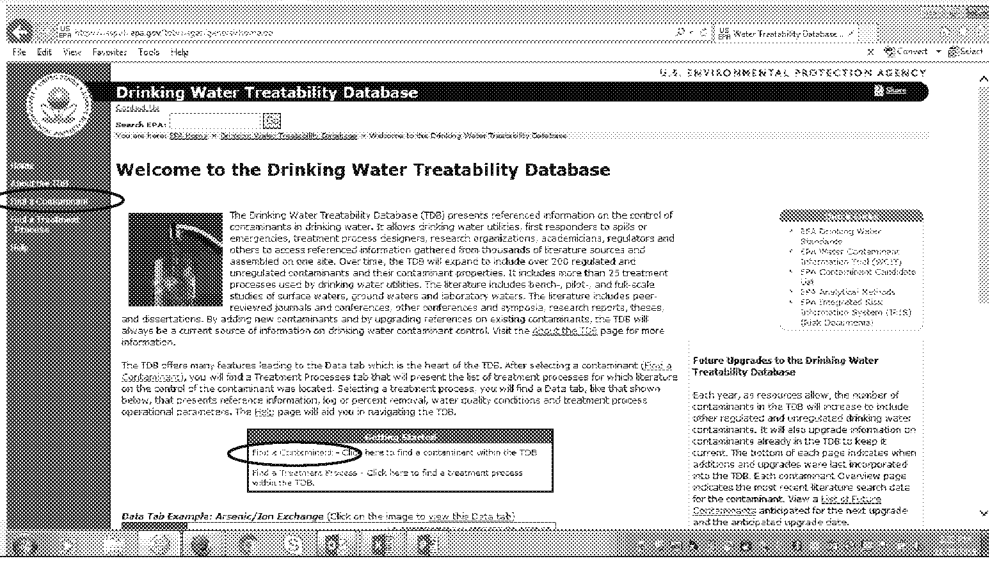
Excavation at a contaminated soil site (Source: Grones Environmental)

# Technical Assistance for States, Tribes, and Communities

- **Problem**: State, Tribes, and Communities sometimes lack full capabilities for managing PFAS risk
- **Action:**
  - Make ORD technical staff available to consult on PFAS issues (e.g. Tech Support Centers)
  - Utilize applied research at impacted sites to develop solutions while also providing technical support to site managers
  - Summarize reoccurring support requests to share lessons learned and identify research needs
  - Collaborate with ECOS and ASTHO to develop case studies for effective risk communication
- **Results/Impacts**: Many other examples of past and ongoing technical assistance
  - Alaska - Site characterization at DoD facility and off-site migration potential
  - Manchester, NH – collaboration on air and water sampling
  - New Jersey – Contaminated sites evaluation in southwestern New Jersey
  - Wurtsmith/Van Etten Lake, MI – provide guidance for collection of lake foams from AFFF contamination and dermal exposure to foams
  - Wyoming, OH – rapid analysis of PFAS cross contamination in water distribution system


Questions?

# EPA's Treatability Database




22

Walk through TDB

## Advantages of Select Treatments

| | |
|---|---|
| Granular Activated Carbon (GAC) | **Most studied technology**<br>**Will remove 100% of the contaminants, for a time**<br>**Good capacity for some PFAS**<br>Will remove a significant number of disinfection byproduct precursors<br>Will help with maintaining disinfectant residuals<br>Will remove many co-contaminants<br>Likely positive impact on corrosion (lead, copper, iron) |
| Anion Exchange Resin (PFAS selective) | **Will remove 100% of the contaminants, for a time**<br>**High capacity for some PFAS**<br>**Smaller beds compared to GAC**<br>Can remove select co-contaminants |
| High Pressure Membranes (Reverse Osmosis or Nanofiltration) | **High PFAS rejection**<br>Will remove many co-contaminants<br>Will remove a significant number of disinfection byproduct precursors<br>Will help with maintaining disinfectant residuals |



Advantages of the treatments

# Issues to Consider

EPA is evaluating these issues to document where and when they will be an issue

| | |
|---|---|
| Granular Activated Carbon (GAC) | **GAC run time for short-chained PFAS (shorter run times)**<br>**Potential overshoot of poor adsorbing PFAS, if not designed correctly**<br>**Reactivation/removal frequency**<br>**Disposal or reactivation of spent carbon** |
| Anion Exchange Resin (PFAS selective) | **Run time for select PFAS (shorter run times)**<br>**Overshoot of poor adsorbing PFAS, if not designed correctly**<br>**Disposal of resin**<br>Unclear secondary benefits |
| High Pressure Membranes (Reverse osmosis or Nanofiltration) | **Capital and operations costs**<br>**Membrane fouling**<br>Corrosion control<br>Lack of options for concentrate stream treatment or disposal |

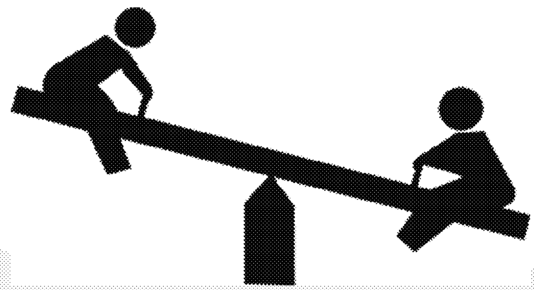


Potential problems with the technologies

# Avoiding Unintended Consequences

**Choice of technology, design, and operations can lead to…**

1) Negative impacts on the performance of the rest of the **treatment system** for other parameters (e.g., decreased control of particulates/pathogens, taste & odor compounds, other source water contaminants)
2) Negative impacts on the **distribution system** (e.g., increased lead, copper, or iron corrosion; disinfection residual maintenance difficulties)



EPA is conducting research on optimizing PFAS treatment



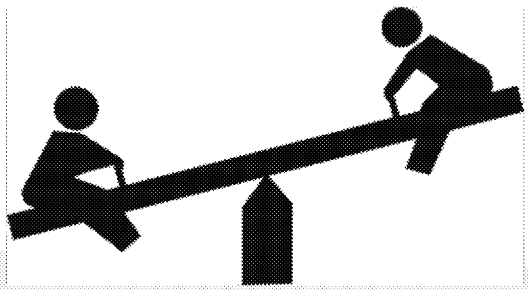
Unintended consequences

EPA

# To Achieve other Positive Benefits

**Choice of technology, design, and operation can have…**

1) Positive impacts on the performance of the rest of the **treatment system** for other parameters (e.g., improved control of particulates/pathogens, taste & odor compounds, industrial contaminants, pesticides, pharmaceuticals, personal care products, endocrine disruptors)
2) Positive impacts on the **distribution system** (e.g., decreased lead, copper, or iron corrosion; better disinfection residual maintenance; fewer disinfection byproducts)



Improved Treatment
Improved Disinfection
Decreased Corrosion

EPA is a resource for communities, states, and regions

How treatment choice, design, and operation can lead to secondary benefits

# EPA's Drinking Water Workshop

## Purpose

- Joint ORD, OGWDW, and ASDWA effort to support the states and other agencies/groups in assisting small drinking water systems.
- Provide in-depth and timely information and training on various solutions and strategies for handling small drinking water system challenges.
- To communicate directly with state personnel and for states to communicate with each other.

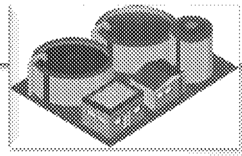
## Benefits to States and EPA

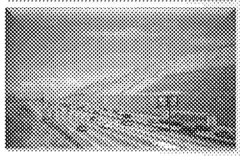
- Provides state agencies with the information and resources they need to communicate the latest scientific advancements
- Provides access to EPA personnel.
- With invaluable information from the states on their current small systems problems, EPA scientists and engineers can modify their research to solve real-world small system problems.

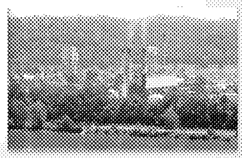
## Target Audiences:

| | |
|---|---|
| Primary | State personnel responsible for drinking water regulations compliance and treatment technologies permitting. |
| Secondary | System owners and operators, local and tribal government personnel, academics, design engineers, technical assistance providers, and consultants. |

# EPA's Site Characterization research...







Analytical methods for complex environmental matrices

## 1. PFAS methods

- Developing non-potable water and solids methods
- Evaluating extraction and lab automation for higher throughput and allowing for smaller sample volumes

## 2. Precursor methods

- Draft analytical methods for a limited number of known precursors of PFAS
- Evaluating the Total Oxidizable Precursor assay to attempt to capture total precursor

## 3. Non-targeted analysis to characterize degradation pathways, precursors, and unknown PFAS

EPA is also working with outside organizations on standardizing sampling protocols for field collection

# Sampling and Analytical issues for Site Characterization

## Observations from preliminary site investigations:

- Limited sampling to characterize sites
- Sampling approach and equipment not evaluated for PFAS
- Site characterization and source identification affected by:
  - Many PFAS-products have varying formulations, chemistrie
  - Lengthy time in environment can result in transformations
  - Co-contaminants present but not sampled simultaneously
  - Remediation technologies used for other contaminants may impact PFAS concentrations and distributions